

# Initial Studies of NSLS2 Dipole with Electromagnetic (EM) Tooth

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# Status of Design Studies of Dipole With a High Field Region

## Design Goal:

- Design should produce a desired field : 0.4 T, with a small ~1 T region.

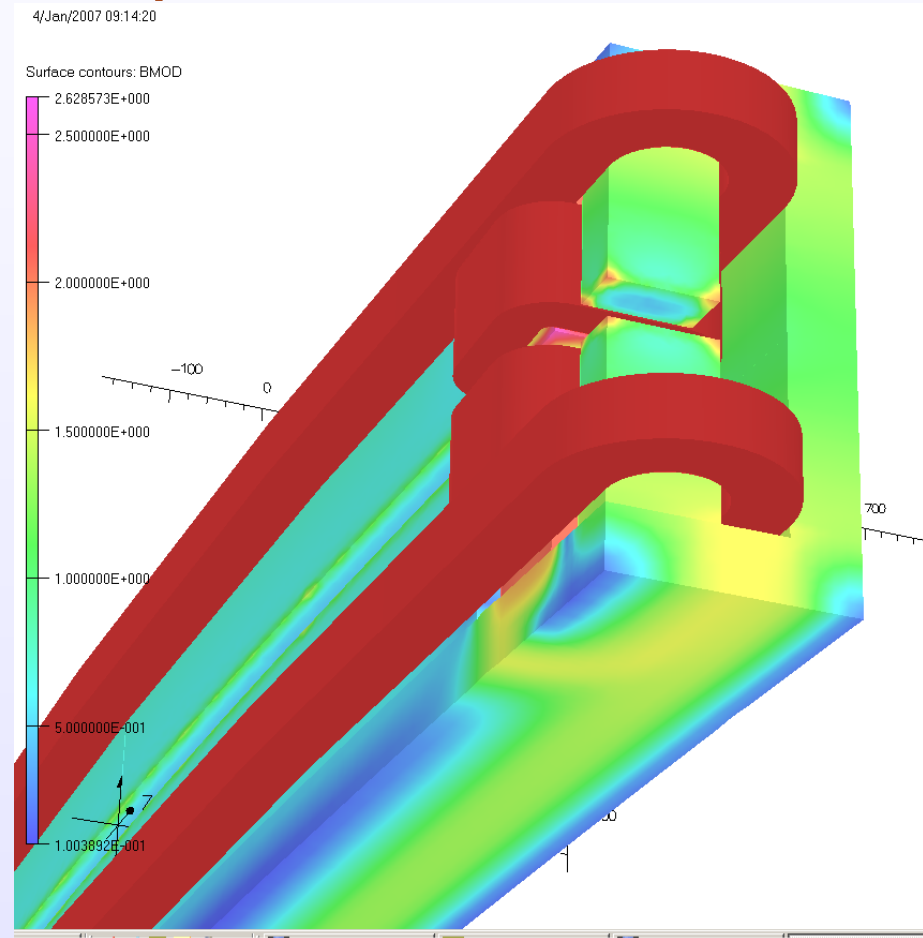
Should 0.4 T be adjusted to keep the original integral field?

- Can acceptable field quality be obtained in the presence of this discontinuity?

- Report on initial investigation.
- This is very much work in progress.
- Please, allow a month or so for more intelligent solutions to appear.

# Computer Model of a Typical Case

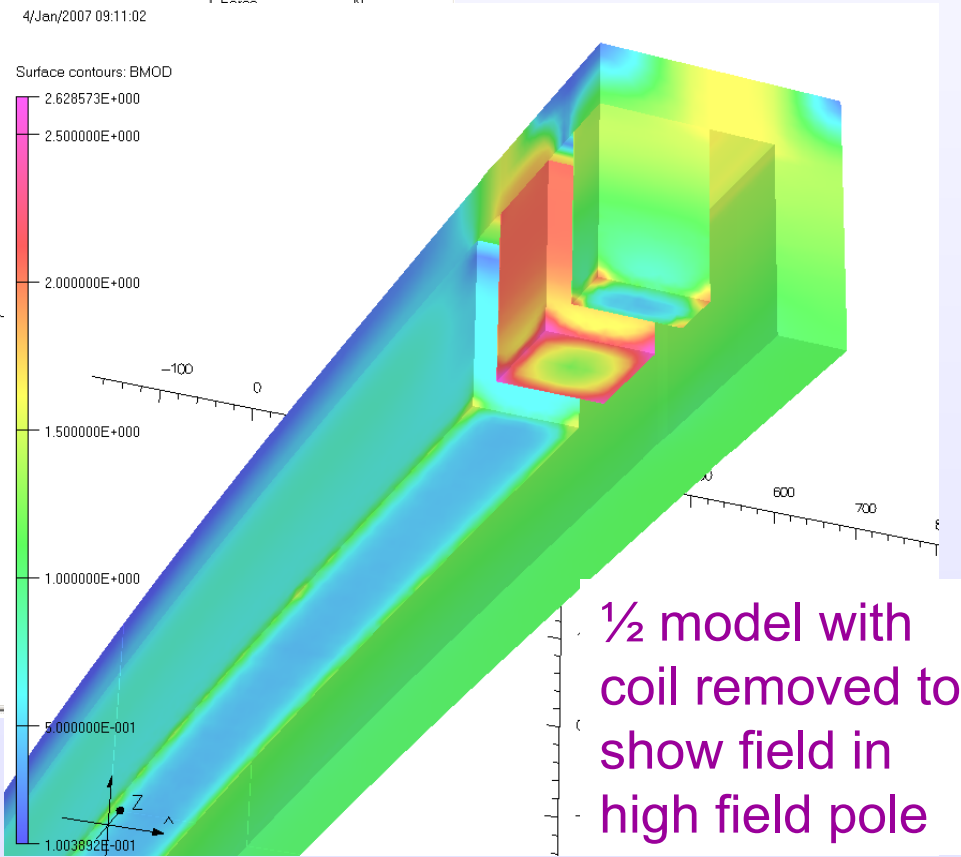
## Complete model with field contour on iron surface



Note: Saturation in high field pole

| UNITS             |                    |
|-------------------|--------------------|
| Length            | mm                 |
| Magn Flux Density | T                  |
| Magn Field        | A m <sup>-1</sup>  |
| Magn Scalar Pot   | A                  |
| Magn Vector Pot   | Wb m <sup>-1</sup> |
| Elec Flux Density | C m <sup>-2</sup>  |
| Elec Field        | V m <sup>-1</sup>  |
| Conductivity      | S mm <sup>-1</sup> |
| Current Density   | A mm <sup>-2</sup> |
| Power             | W                  |
| Energy            | J                  |

Width of High Field Pole  
= 100 mm wide  
(also has 50 mm gap  
on either side for coils)

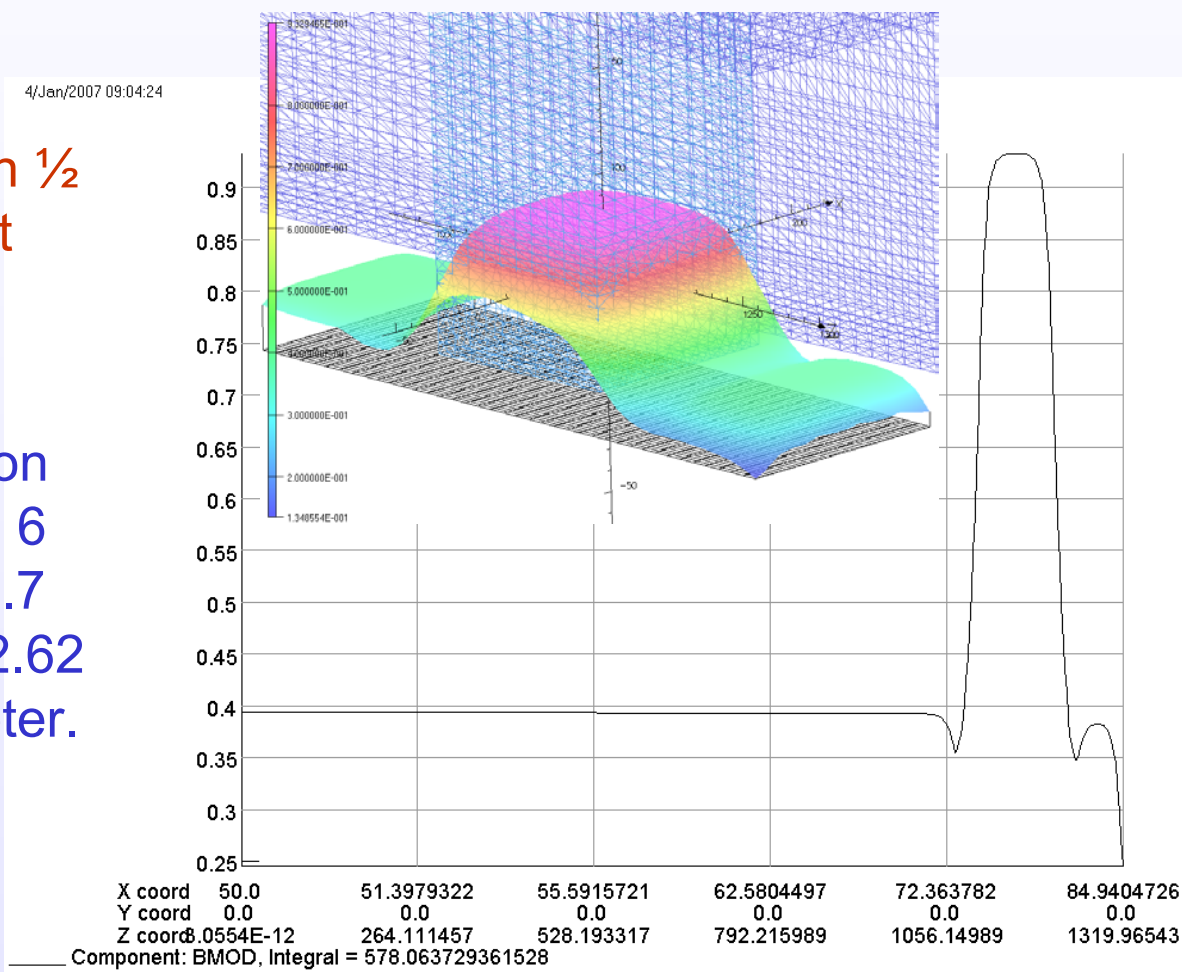


½ model with  
coil removed to  
show field in  
high field pole

# Field Profile on Magnet Axis in 100 mm Wide Pole Case

Field profile in 1/2  
of the magnet  
(3 degrees)

Total deflection  
per magnet = 6  
degrees (104.7  
mrad) =  $0.4 \times 2.62$   
= 1.048 T.meter.



| UNITS             |                    |
|-------------------|--------------------|
| Length            | mm                 |
| Magn Flux Density | T                  |
| Magn Field        | A m <sup>-1</sup>  |
| Magn Scalar Pot   | A                  |
| Magn Vector Pot   | Wb m <sup>-1</sup> |
| Elec Flux Density | C m <sup>-2</sup>  |
| Elec Field        | V m <sup>-1</sup>  |
| Conductivity      | S mm <sup>-1</sup> |
| Current Density   | A mm <sup>-2</sup> |
| Power             | W                  |
| Force             | N                  |
| Energy            | J                  |

| PROBLEM DATA                       |  |
|------------------------------------|--|
| Is2-cu4-i6a2_78.op3                |  |
| TOSCA Magnetostatic                |  |
| Nonlinear materials                |  |
| Simulation No 1 of 1               |  |
| 1236259 elements                   |  |
| 211353 nodes                       |  |
| 4 conductors                       |  |
| Nodally interpolated fields        |  |
| Activated in global coordinates    |  |
| Reflection in XY plane (Z field=0) |  |

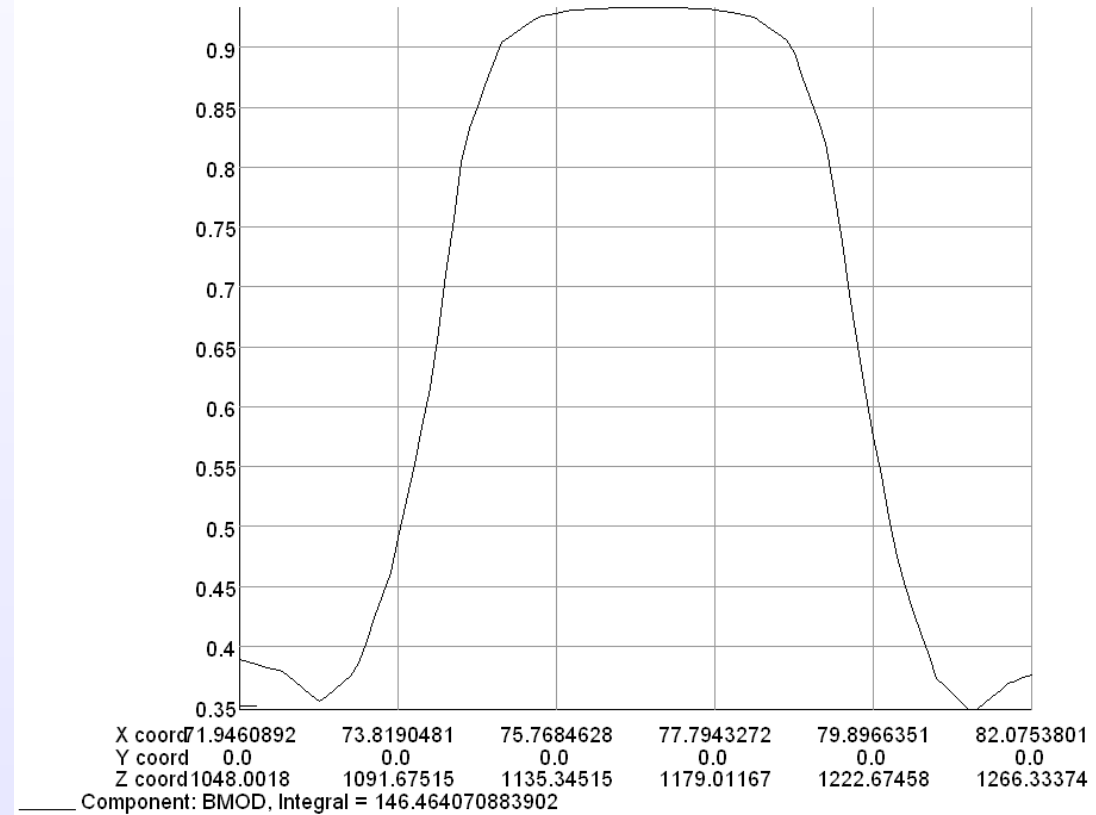
| Field Point Local Coordinates |          |
|-------------------------------|----------|
| Local                         | = Global |

**Desired deflection in high field insert 2 mrad**

# Field Profile from 2.4 degrees to 2.9 degrees

Desired deflection in high field insert 2 mrad

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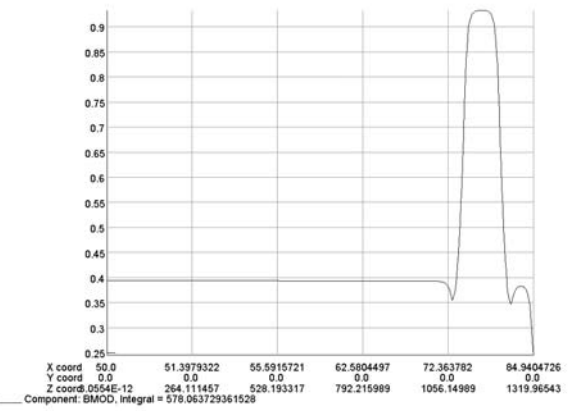
**UNITS**  
Length mm  
Magn Flux Density T  
Magn Field A m<sup>-1</sup>  
Magn Scalar Pot A  
Magn Vector Pot Wb m<sup>-1</sup>  
Elec Flux Density C m<sup>-2</sup>  
Elec Field V m<sup>-1</sup>  
Conductivity S mm<sup>-1</sup>  
Current Density A mm<sup>-2</sup>  
Power W  
Force N  
Energy J

**PROBLEM DATA**  
Is2-cu4-i6a2\_78.op3  
TOSCA Magnetostatic  
Nonlinear materials  
Simulation No 1 of 1  
1236259 elements  
211353 nodes  
4 conductors  
Nodally interpolated fields  
Activated in global coordinates

**Field Point Local Coordinates**  
Local = Global

**100 mm pole  
gives ~50 mm  
flat top and ~100  
mm half width**

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**UNITS**  
Length mm  
Magn Flux Density T  
Magn Field A m<sup>-1</sup>  
Magn Scalar Pot A  
Magn Vector Pot Wb m<sup>-1</sup>  
Elec Flux Density C m<sup>-2</sup>  
Elec Field V m<sup>-1</sup>  
Conductivity S mm<sup>-1</sup>  
Current Density A mm<sup>-2</sup>  
Power W  
Force N  
Energy J

**PROBLEM DATA**  
Is2-cu4-i6a2\_78.op3  
TOSCA Magnetostatic  
Nonlinear materials  
Simulation No 1 of 1  
1236259 elements  
211353 nodes  
4 conductors  
Nodally interpolated fields  
Activated in global coordinates  
Reflection in XY plane (Z field=0)

**Field Point Local Coordinates**  
Local = Global

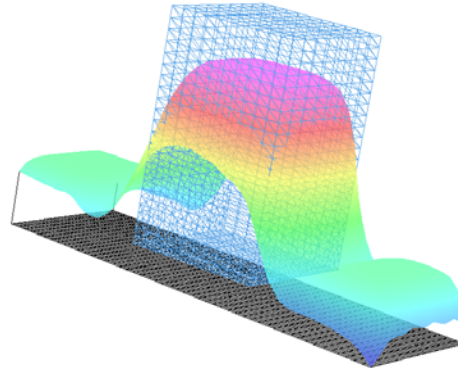
# Field Quality

Calculations of 3-d harmonics are yet to be performed. However, some understanding can be obtained by studying the field profile.

5/Jan/2007 09:15:08

Map contours: BMOD  
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8.000000E-001  
7.000000E-001  
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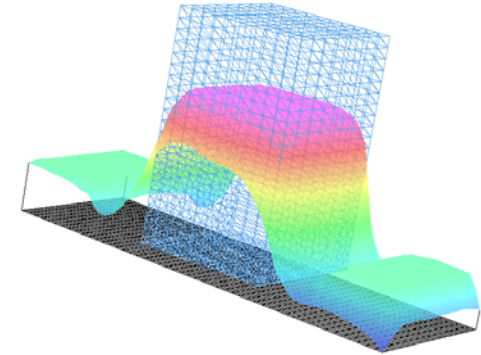
$Y = 0$  mm



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Map contours: BMOD  
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8.000000E-001  
7.000000E-001  
6.000000E-001  
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$Y = 10$  mm



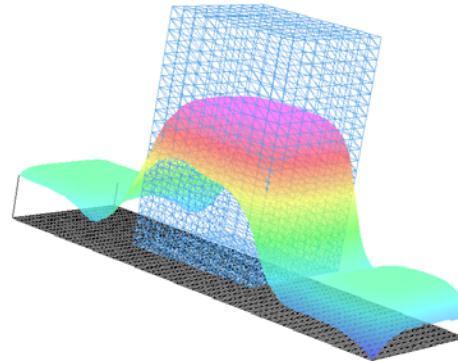
Vector Fields  
software for electromagnetic design

Vector Fields  
software for electromagnetic design

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Map contours: BMOD  
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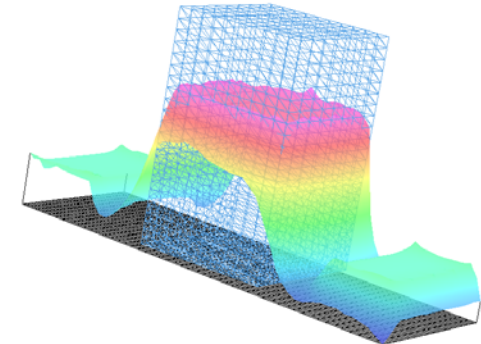
$Y = 5$  mm



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Map contours: BMOD  
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1.000000E+000  
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7.000000E-001  
6.000000E-001  
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4.000000E-001  
3.000000E-001  
2.000000E-001  
1.537420E-001

$Y = 15$  mm

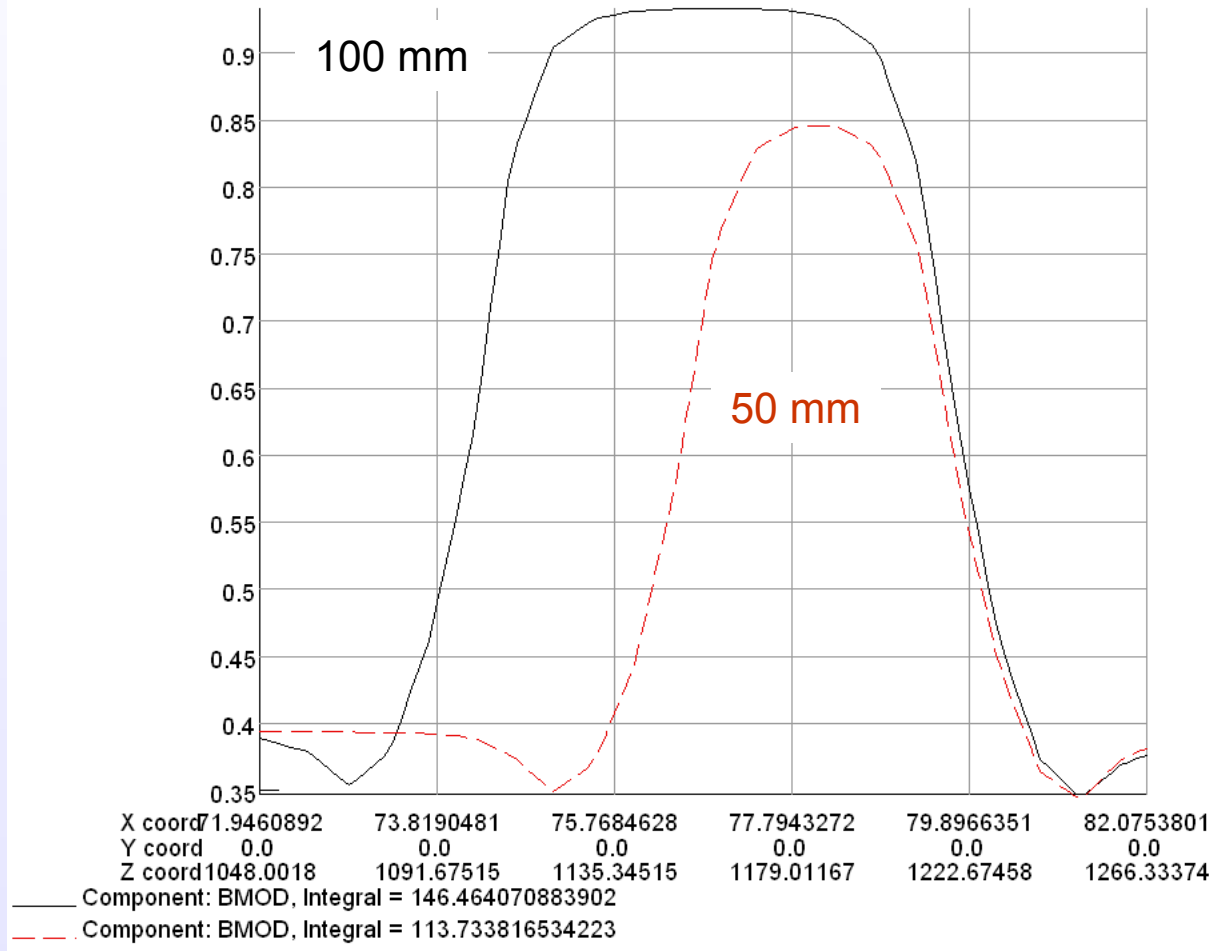


Vector Fields  
software for electromagnetic design

Vector Fields  
software for electromagnetic design

# Case Study of Narrower Pole (50 mm instead of 100 mm wide)

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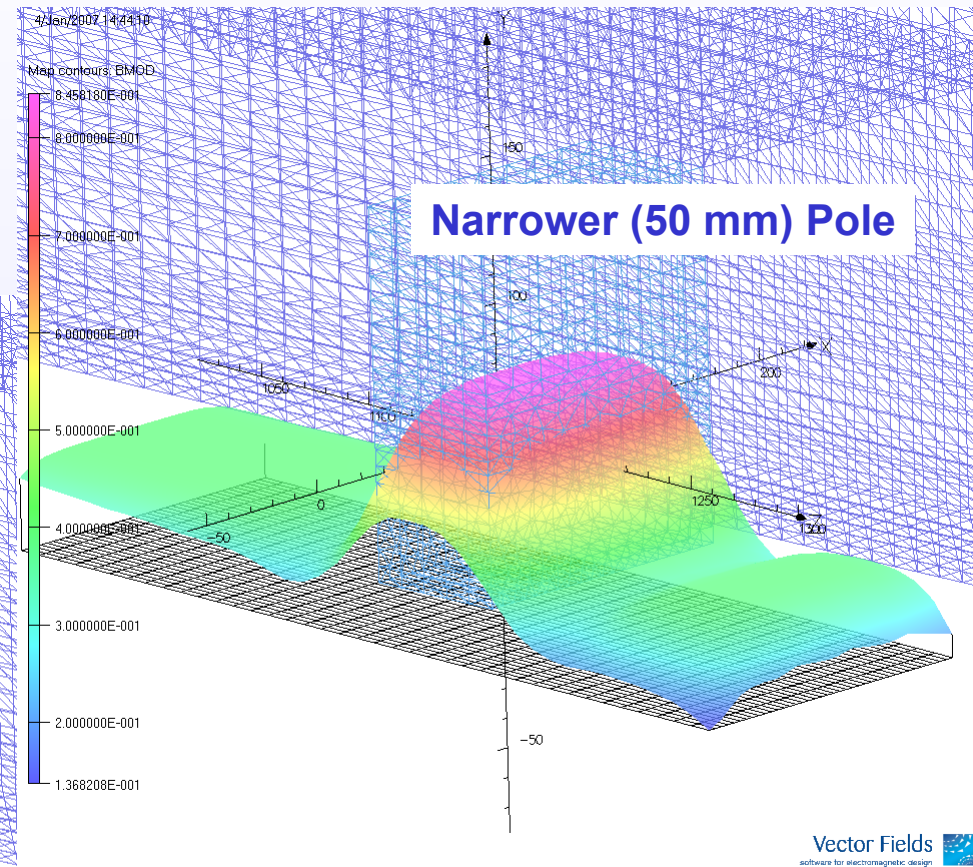
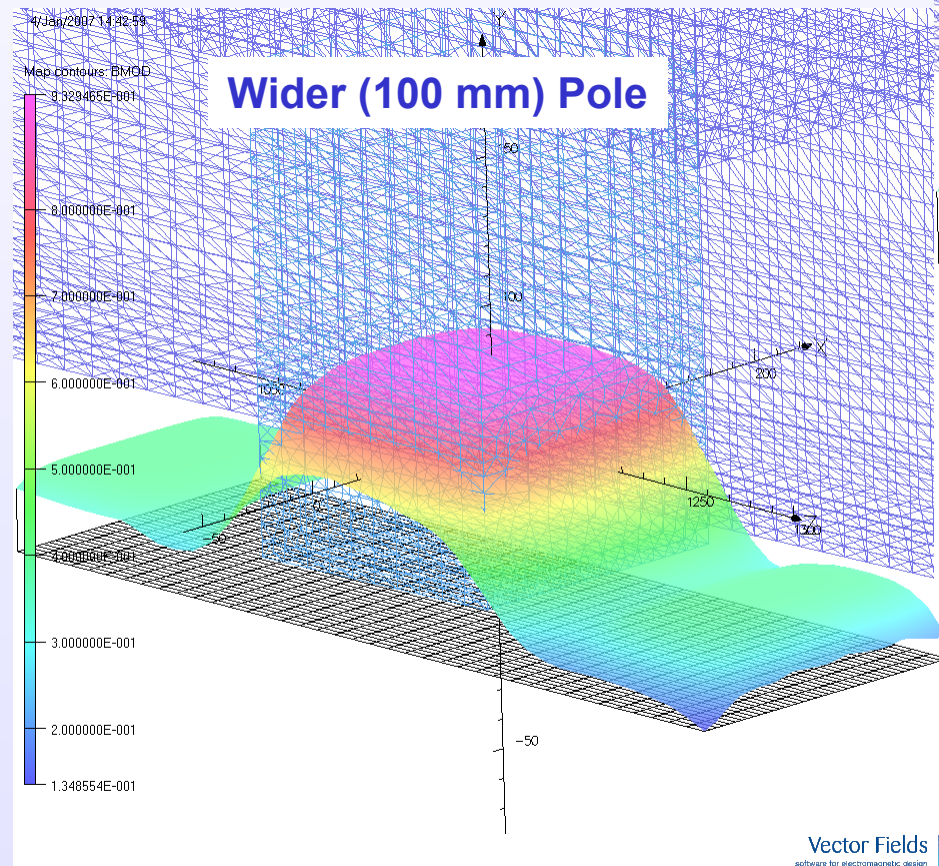
| UNITS             |                    |
|-------------------|--------------------|
| Length            | mm                 |
| Magn Flux Density | T                  |
| Magn Field        | A m <sup>-1</sup>  |
| Magn Scalar Pot   | A                  |
| Magn Vector Pot   | Wb m <sup>-1</sup> |
| Elec Flux Density | C m <sup>-2</sup>  |
| Elec Field        | V m <sup>-1</sup>  |
| Conductivity      | S mm <sup>-1</sup> |
| Current Density   | A mm <sup>-2</sup> |
| Power             | W                  |
| Force             | N                  |
| Energy            | J                  |

| PROBLEM DATA                    |  |
|---------------------------------|--|
| Is2-cu4-i5a3_1.op3              |  |
| TOSCA Magnetostatic             |  |
| Nonlinear materials             |  |
| Simulation No 1 of 1            |  |
| 1228657 elements                |  |
| 210066 nodes                    |  |
| 4 conductors                    |  |
| Nodally interpolated fields     |  |
| Activated in global coordinates |  |

| Field Point Local Coordinates |  |
|-------------------------------|--|
| Local = Global                |  |

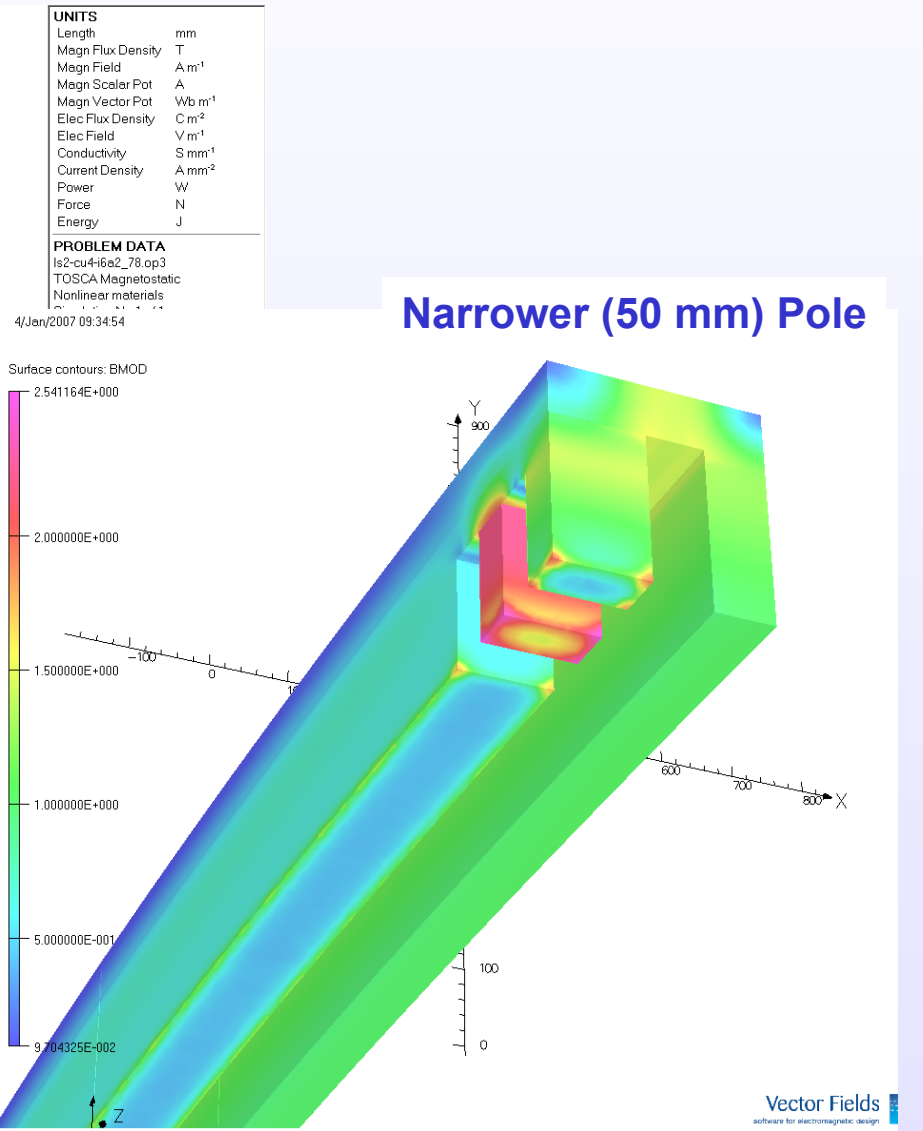
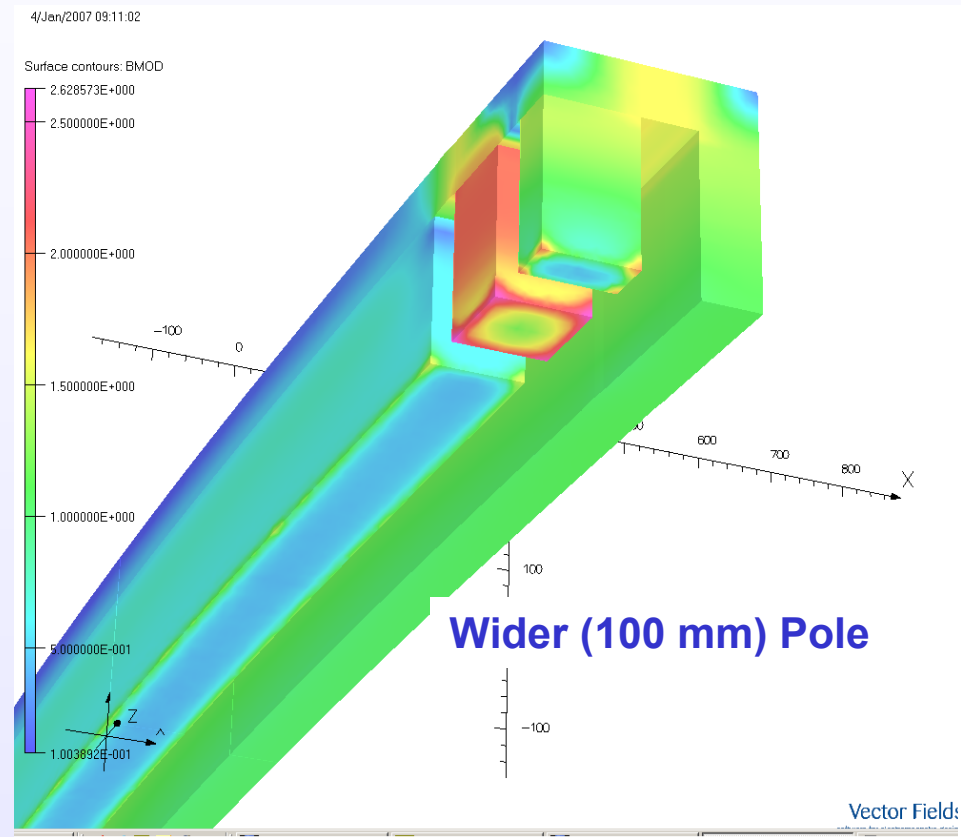


# Field in 100 mm and 50 mm wide high field poles powered with $\Delta I$

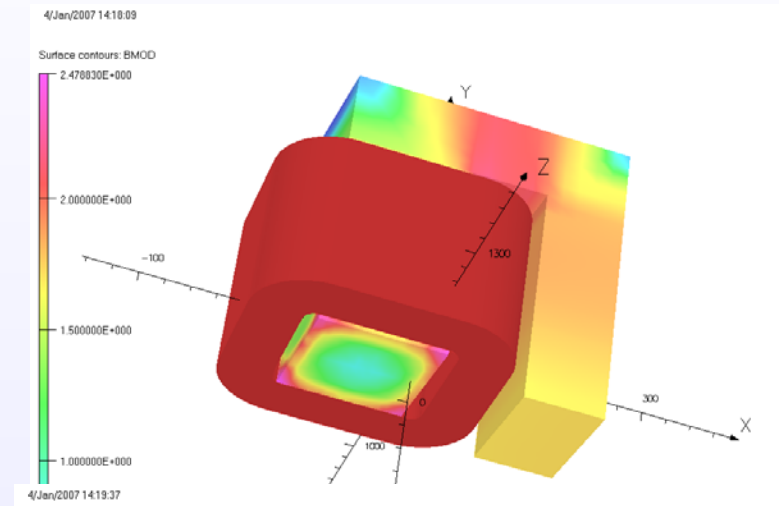




# Case Study of Narrower Pole (50 mm instead of 100 mm wide)



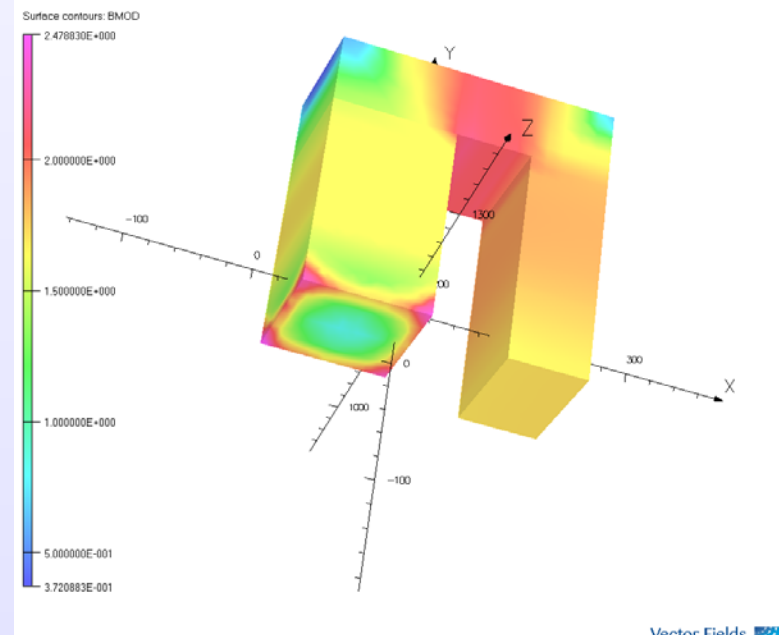
# Field in Short (100 mm X 100 mm) Magnet



**UNITS**

|                   |                    |
|-------------------|--------------------|
| Length            | mm                 |
| Magn Flux Density | T                  |
| Magn Field        | A m <sup>-1</sup>  |
| Magn Scalar Pot   | A                  |
| Magn Vector Pot   | Vb m <sup>-1</sup> |
| Elec Flux Density | C m <sup>-2</sup>  |
| Elec Field        | V m <sup>-1</sup>  |
| Conductivity      | S mm <sup>-1</sup> |
| Current Density   | A mm <sup>-2</sup> |
| Power             | W                  |
| Force             | N                  |
| Energy            | J                  |

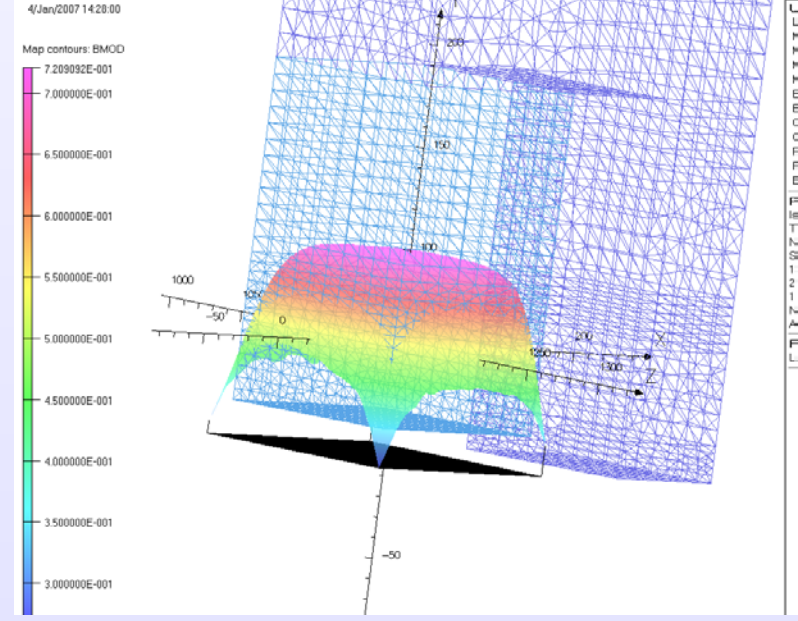
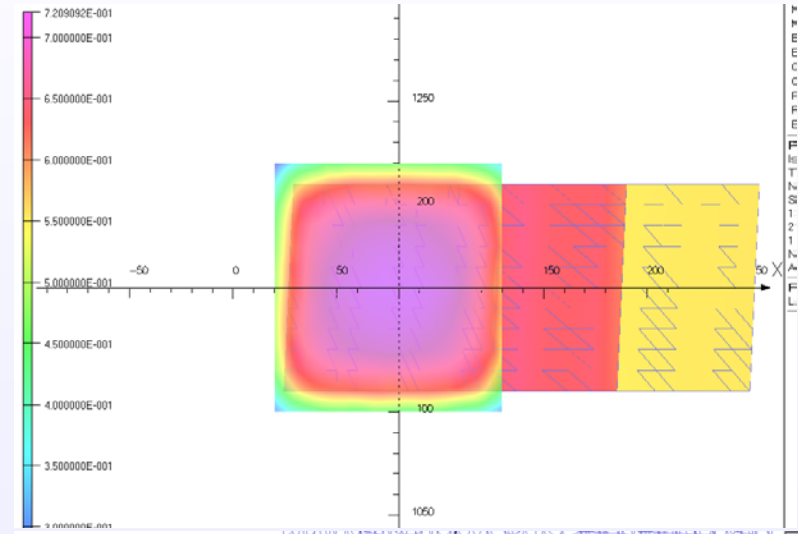
**PROBLEM DATA**  
Is2-cu4-short-lla2\_78.ep3  
TOSCA Magnetostatic  
Nonlinear materials  
Simulation No 1 of 1  
123659 elements  
211353 nodes  
1 conductor  
Nodally interpolated fields  
Activated in global coordinates  
**Field Point Local Coordinates**  
Local = Global



**UNITS**

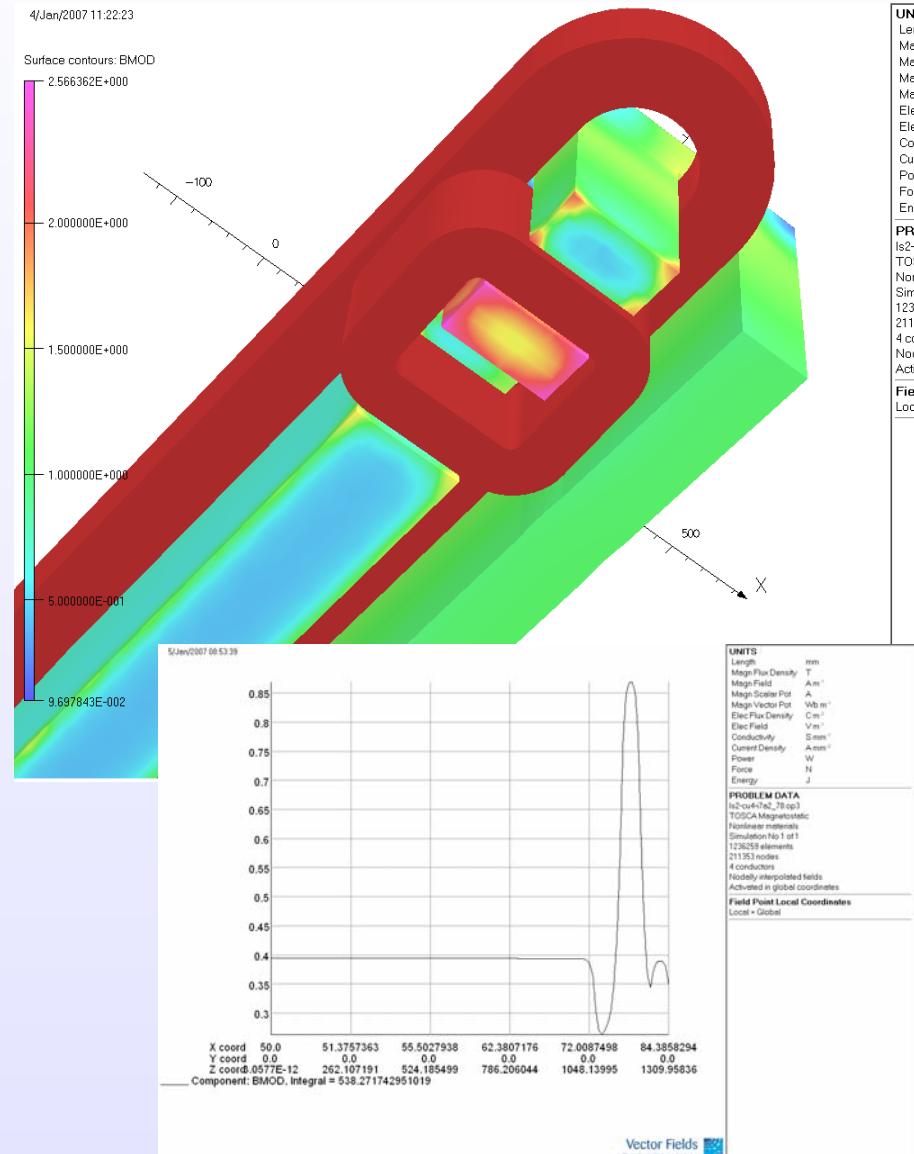
|                   |                    |
|-------------------|--------------------|
| Length            | mm                 |
| Magn Flux Density | T                  |
| Magn Field        | A m <sup>-1</sup>  |
| Magn Scalar Pot   | A                  |
| Magn Vector Pot   | Vb m <sup>-1</sup> |
| Elec Flux Density | C m <sup>-2</sup>  |
| Elec Field        | V m <sup>-1</sup>  |
| Conductivity      | S mm <sup>-1</sup> |
| Current Density   | A mm <sup>-2</sup> |
| Power             | W                  |
| Force             | N                  |
| Energy            | J                  |

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Is2-cu4-short-lla2\_78.ep3  
TOSCA Magnetostatic  
Nonlinear materials  
Simulation No 1 of 1  
123659 elements  
211353 nodes  
1 conductor  
Nodally interpolated fields  
Activated in global coordinates  
**Field Point Local Coordinates**  
Local = Global



Vector Fields

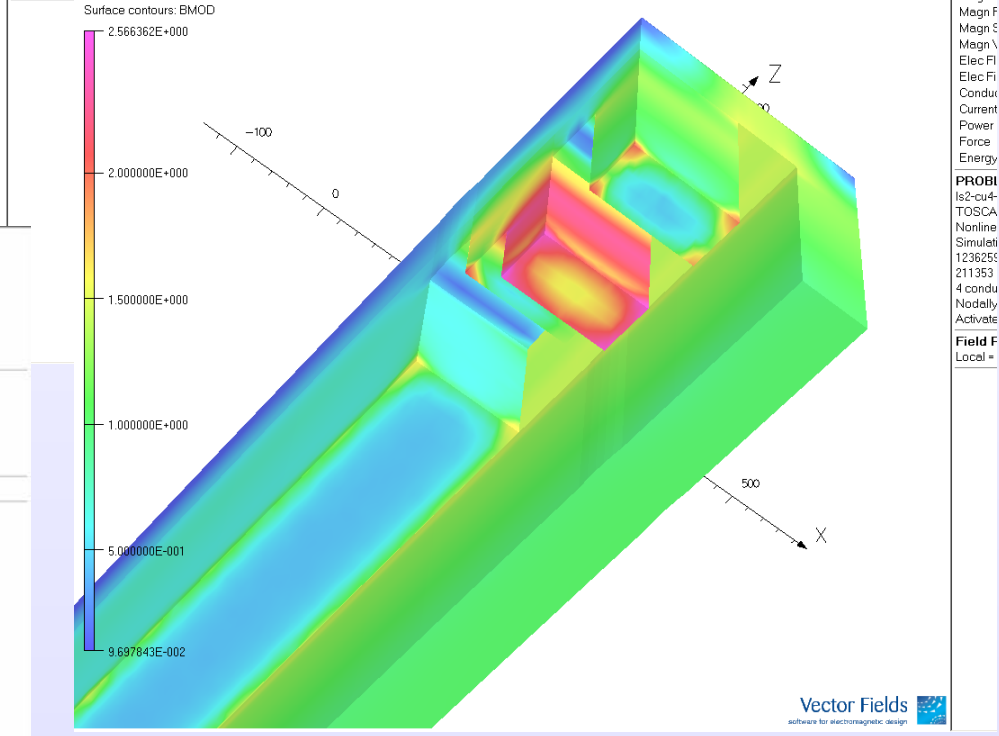
# Cutout Pole to Reduce Saturation



| UNITS             |                    |
|-------------------|--------------------|
| Length            | mm                 |
| Magn Flux Density | T                  |
| Magn Field        | A m <sup>-1</sup>  |
| Magn Scalar Pot   | A                  |
| Magn Vector Pot   | Wb m <sup>-1</sup> |
| Elec Flux Density | C m <sup>-2</sup>  |
| Elec Field        | V m <sup>-1</sup>  |
| Conductivity      | S mm <sup>-1</sup> |
| Current Density   | A mm <sup>-2</sup> |
| Power             | W                  |
| Force             | N                  |
| Energy            | J                  |

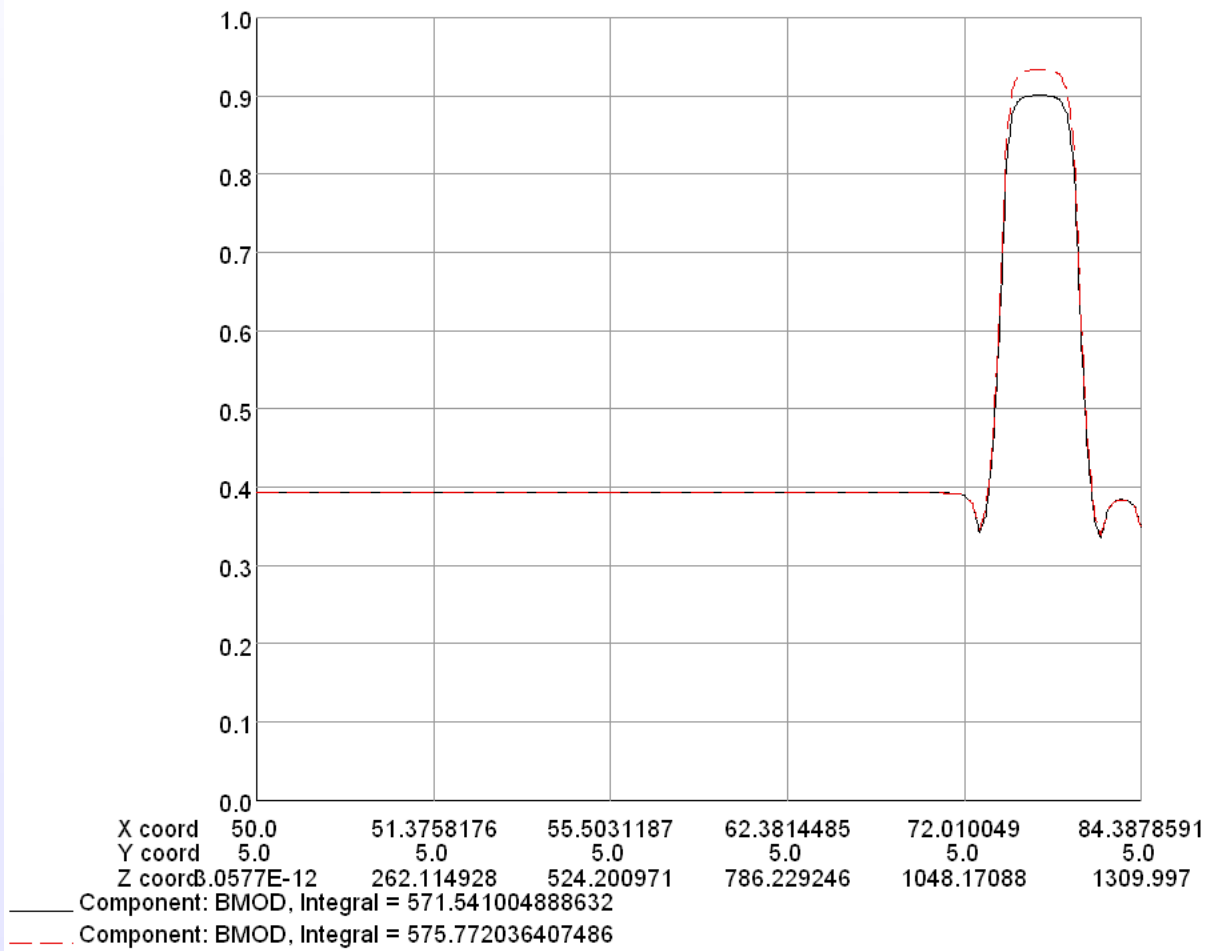
| PROBLEM DATA                    |  |
|---------------------------------|--|
| Is2-cu4-i7a2_78.op3             |  |
| TOSCA Magnetostatic             |  |
| Nonlinear materials             |  |
| Simulation No 1 of 1            |  |
| 1236259 elements                |  |
| 211353 nodes                    |  |
| 4 conductors                    |  |
| Nodally interpolated fields     |  |
| Activated in global coordinates |  |
| 4/Jen/2007 11:20:22             |  |

| Field Point  |  |
|--------------|--|
| Local = Glol |  |



# Non-linear Excitation

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| UNITS             |                    |
|-------------------|--------------------|
| Length            | mm                 |
| Magn Flux Density | T                  |
| Magn Field        | A m <sup>-1</sup>  |
| Magn Scalar Pot   | A                  |
| Magn Vector Pot   | Wb m <sup>-1</sup> |
| Elec Flux Density | C m <sup>-2</sup>  |
| Elec Field        | V m <sup>-1</sup>  |
| Conductivity      | S mm <sup>-1</sup> |
| Current Density   | A mm <sup>-2</sup> |
| Power             | W                  |
| Force             | N                  |
| Energy            | J                  |

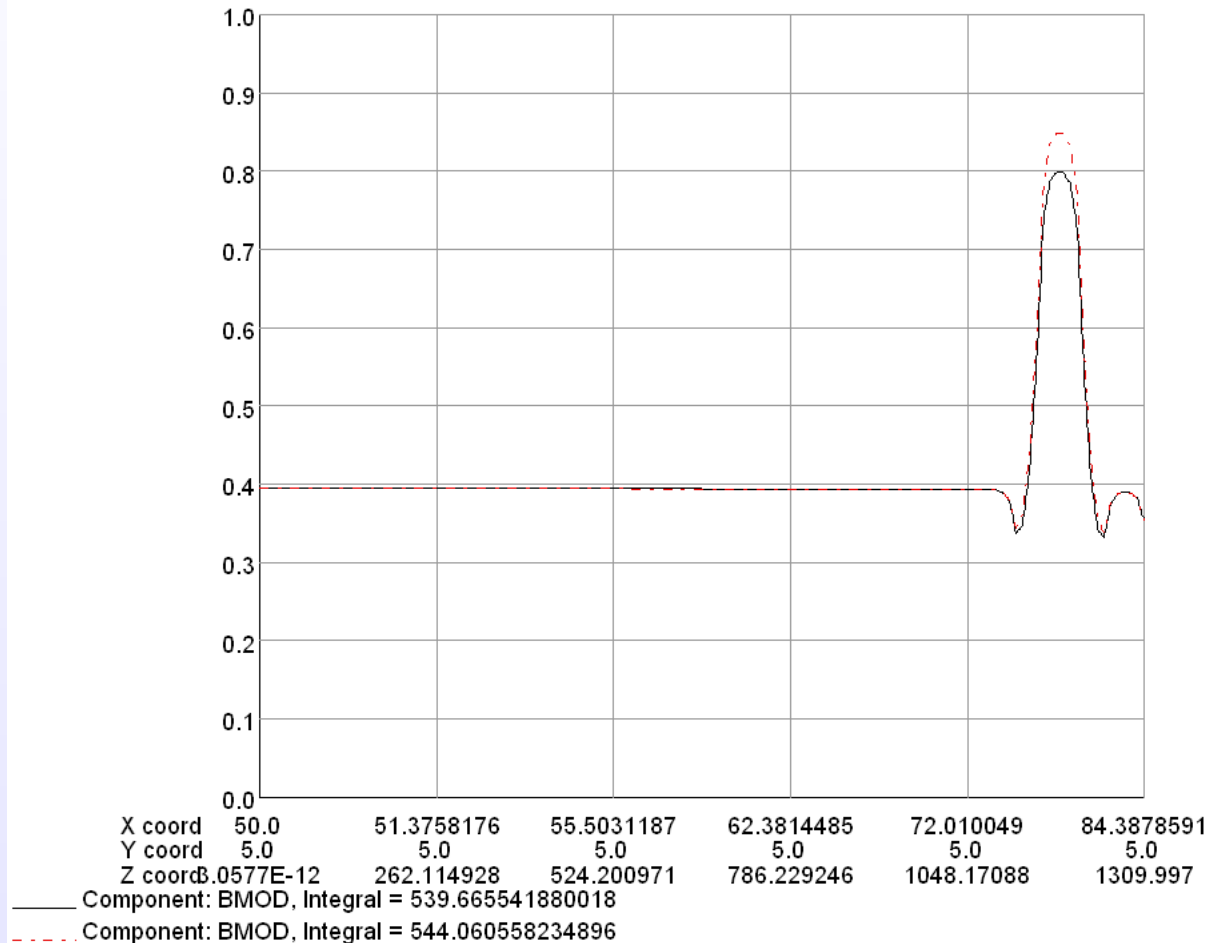
| PROBLEM DATA                    |  |
|---------------------------------|--|
| Is2-cu4-i6a2_78.op3             |  |
| TOSCA Magnetostatic             |  |
| Nonlinear materials             |  |
| Simulation No 1 of 1            |  |
| 1236259 elements                |  |
| 211353 nodes                    |  |
| 4 conductors                    |  |
| Nodally interpolated fields     |  |
| Activated in global coordinates |  |

| Field Point Local Coordinates |  |
|-------------------------------|--|
| Origin: 0.0, 5.0, 0.0         |  |
| Local XYZ = Global XYZ        |  |

**Wider pole.  
Linear scaling  
would have  
raised field to 1 T.**

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# Non-linear Excitation



## UNITS

|                   |                    |
|-------------------|--------------------|
| Length            | mm                 |
| Magn Flux Density | T                  |
| Magn Field        | A m <sup>-1</sup>  |
| Magn Scalar Pot   | A                  |
| Magn Vector Pot   | Wb m <sup>-1</sup> |
| Elec Flux Density | C m <sup>-2</sup>  |
| Elec Field        | V m <sup>-1</sup>  |
| Conductivity      | S mm <sup>-1</sup> |
| Current Density   | A mm <sup>-2</sup> |
| Power             | W                  |
| Force             | N                  |
| Energy            | J                  |

## PROBLEM DATA

Is2-cu4-i5a3\_1.op3  
TOSCA Magnetostatic  
Nonlinear materials  
Simulation No 1 of 1  
1228657 elements  
210066 nodes  
4 conductors  
Nodally interpolated fields  
Activated in global coordinates

## Field Point Local Coordinates

Origin: 0.0, 5.0, 0.0  
Local XYZ = Global XYZ

**Narrow pole.  
Linear scaling  
would have  
raised field to 1 T.**